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HETERODYNE METHOD OF MEASURING THE DIFFUSIVE COMPONENT OF LASER MIRRORS

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Translation of "Geterodinnyy metod izmereniya diffuznoy sostavlyayushchey lazernykh zerkal," Kratkiye Soobshcheniya po Fizike, FIAN, No. 10, 1971, pp. 10-15

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16. Abstract

A modified Michelson interferometer, for measurement of the diffusive component of laser mirrors at various angles of incidence by the heterodyne method, is described and illustrated. Radiation diffusively reflected in the direction opposite to the incident beam was recorded by use of a GeHg photoresistor at liquid nitrogen temperature. Curves of the diffusive reflection power vs. angle of incidence and data on the contribution of the diffusive component are presented.

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HETERODYNE METHOD OF MEASURING THE DIFFUSIVE COMPONENT OF LASER MIRRORS

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A laser mirror is characterized by three basic parameters: /10*
the mirror component, the diffusive component and intrinsic heat losses. In practice, measurement of the mirror component with high accuracy is a very complicated task. A highly effective calorimetric method has been proposed for measurement of the intrinsic heat losses [1]. Measurement of the total effect of heat and diffusive losses is accomplished by the quite complicated and not always convenient "light trap" method [2].

A direct knowledge of just the diffusive component is important for many tasks. In our experiments, the diffusive component of laser mirrors was measured by the heterodyne method. The virtues of this method, a narrow detection pattern and high sensitivity [3], make it efficient in measurement of laser mirror characteristics.

Experiments to determine the reflection coefficients of the mirror surfaces were carried out by the scheme presented in Fig. 1. Radiation from a CO_2 laser hit a modified Michelson interferometer. One of the mirrors of a regular interferometer was replaced by the rotating sample being studied. Radiation scattered by the surface created a Doppler-shifted signal, which was added to the heterodyne radiation, reflected from the mirror in the /12
other arm of the interferometer, and which was nonfrequency-shifted, in the beam-splitting mirror. The entire setup, with the exception of the rotating mirror surface, was mounted on a massive

* Numbers in the margin indicate pagination in the foreign text.

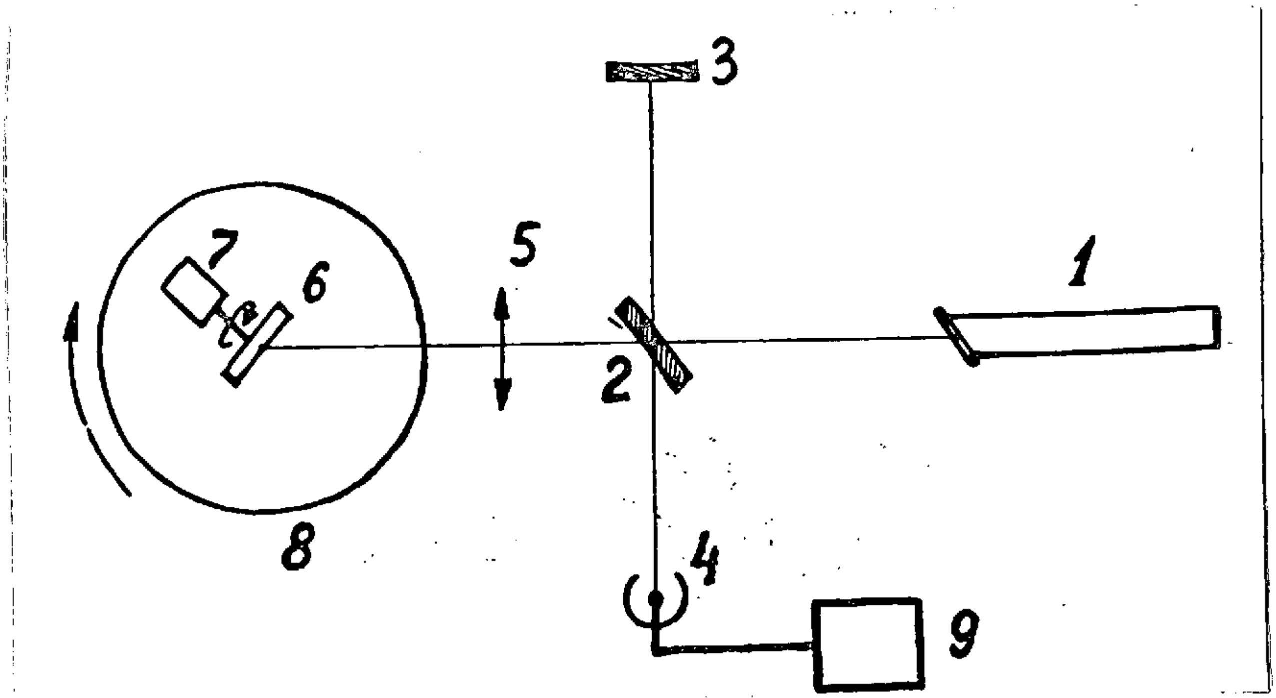

Fig. 1. Block diagram of setup: 1. LG-17 laser; 2. beam-splitting mirror; 3. heterodyne mirror; 4. Ge-Hg detector; 5. lens; 6. test mirror; 7. motor; 8. rotary optical bench; 9. V6-1 selective voltmeter.

steel slab, installed on a shock-absorbing pad. A high-resistance germanium p-type plate was used as the beam splitter; one of its surfaces was transparent to the 10.6 μm wavelength. The working mirror of the interferometer was made of gold-coated fused quartz. An NaCl lens with 30 cm focal length, located in the path of the signal beam, focused the laser radiation on the surface being studied and provided spatial coherence of the scattered radiation through the detector aperture. The mirror surface rotated at a rate of 3000 rpm, and it was attached to an adjustable support. The adjustable support was installed on a rotary table, permitting the angle of incidence of the signal beam to be changed. The accuracy of the angle setting was 0.1°. The CO_2 laser emission was focused on the vertical axis of symmetry of the rotating mirror, so that, when changing the angle of incidence, the position of the focal point on the surface being studied was not changed.

Radiation, reflected diffusively in the direction opposite the incident beam, was recorded. In this manner, a change in the angle of incidence made it possible to measure the angular dependence of the diffusive component.

A single-mode CO_2 laser, with 5 W output power, was used in the experiments. A GeHg photoresistor, operating at liquid nitrogen temperature, was used as the laser emission detector. The intermediate frequency signal was measured with a V6-1 selective voltmeter.

Gold mirrors were studied. A portion of the mirrors was fabricated, by means of vacuum sputtering of gold (purity greater than 99.99) on a polished K-8 glass substrate. The cleaned substrates were placed in a sputtering unit. Chromium was deposited on the substrate beforehand, to provide better adhesion of the gold coating to the surface of the substrate. Evaporation was /13 carried out in a vacuum of 10^{-5} mm Hg, provided by an oil-diffusion pump, using a nitrogen-cooled trap to freeze out the oil vapors. The evaporators were placed under the substrates, in such a manner that the thickness of the metal was uniform to within 8-10% at all points on the samples. The coating thickness was 1500 A.

The results of measurement of the diffusive component for various laser mirrors are presented in Fig. 2: curve No. 1, freshly-sputtered mirror; curve No. 2, gold mirror used for a period of 1 month in the open air; curve No. 3, mirror fabricated by optical polishing of a gold bar.

The curves in Fig. 2 show that, with a 2° change in angle of incidence from the normal, the amplitude of the back-reflected signal decreases by 10^3-10^4 times. Analysis of the angular dependence shows that, at angle of incidence greater than 20°, the

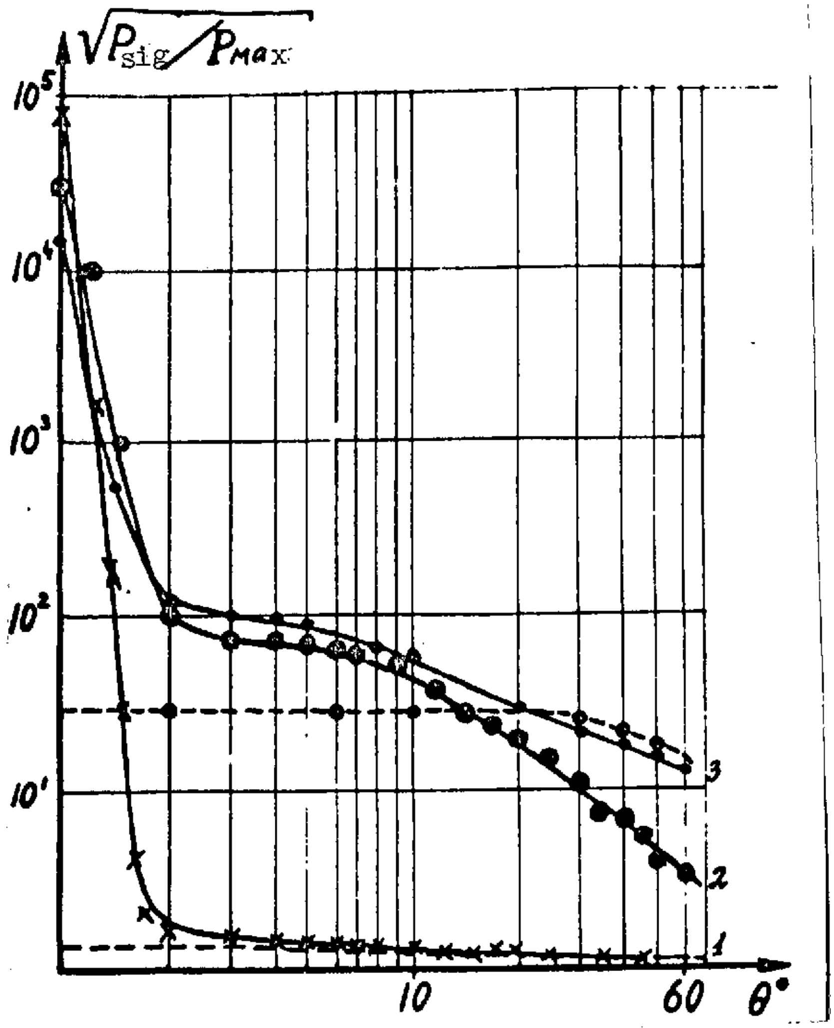

Fig. 2. Angular dependence of diffusive component for gold laser mirrors.

power reflected backward is described well by Lambert's law. (The curve $A \sim A_0 \cos^2 \phi$ is plotted on Fig. 2 with a dashed line.) The deviation of sample No. 3 from Lambert's law apparently is caused by the structure of the sample surface.

The contribution of the diffusive component can be estimated, on the basis of the results obtained. The results of the estimates are presented in Table 1.

TABLE 1

Sample No.	1	2	3
A^2_{dif}/A^2_{mir}	4.10^{-4}	0.0411	0.0676

It must also be noted that, on the basis of the results obtained, the sizes of microirregularities on the mirror surface can be estimated.

In this manner, the use of the heterodyne method permits quite accurate measurement of one of the basic characteristics of a laser mirror, the diffusive component.

In conclusion, the authors express thanks to A.M. Prokhorov, for continual interest in the work, and to A.V. Shirokov for fabricating the mirror. /15

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